Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

Mining Research Laboratories
Laboratoires de recherche minière

PRE-MINING AND PILLAR STRESS DETERMINATIONS AT THE H-W MINE, WESTMIN RESOURCES, B.C.

B. ARJANG AND K. STEVENS

DIVISION REPORT MRL 91-144(TR) DECEMBER 1991

Canada

PRE-MINING AND PILLAR STRESS DETERMINATIONS AT THE H-W MINE, WESTMIN RESOURCES, B.C.

B. ARJANG AND K. STEVENS

DIVISION REPORT MRL 91-144(TR) DECEMBER 1991

17 pp

92-04864/

PRE-MINING AND PILLAR STRESS DETERMINATIONS AT THE H-W MINE WESTMIN RESOURCES, B.C.

B. Arjang* and K. Stevens**

ABSTRACT

Triaxial overcoring stress measurements were conducted for stability evaluation of the underground structures and barrier pillars at the H-W mine of Westmin Resources, Vancouver Island, B.C. Pre-mining and pillar stresses were determined at a depth of about 650 m below surface.

The pre-mining ground stresses determined indicate that the maximum and intermediate principal compressive stresses are horizontal in SEE and NNE directions, respectively. The ratio of maximum to minimum horizontal stress ranges from 1.6 to 2.0. With a vertical stress gradient of 0.028 MPa/m for an average depth of 650 m, the maximum horizontal stress is 1.9 $\pm$ 0.12 times, and the minimum horizontal stress is 1.1 $\pm$ 0.07 times the measured vertical stress.

The results of the present pillar stress determinations are not conclusive and further overcoring measurements are required to verify the stress data obtained.

Key words: Pre-mining stress; Pillar stress; Overcoring measurement.

*Research Scientist; **Physical Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario.

DÉTERMINATION DES CONTRAINTES D'EXPLORATION PRÉLIMINAIRE ET DES CONTRAINTES DANS LES PILIERS À LA MINE H-W WESTMIN RESOURCES (C.-B.)

B. Arjang* et K. Stevens**

RÉSUMÉ

On a effectué des mesures triaxiales des contraintes de surcarottage en vue d'évaluer la stabilité des structures souterraines et des massifs à la mine H-W de la Westmin Resources sur l'île de Vancouver (C.-B.). Les contraintes d'exploration préliminaire et les contraintes dans les piliers ont été déterminées à une profondeur d'environ 650 m sous la surface.

Les valeurs obtenues pour l'exploration préliminaire dans le sol montrent que les principales contraintes de compression maximales et intermédiaires sont horizontales dans des directions SEE et NNE respectivement. Le rapport de la contrainte horizontale maximale à la contrainte horizontale minimale va de 1,6 à 2,0. Avec un gradient de contrainte vertical de 0,028 MPa/m pour une profondeur moyenne de 650 m, la contrainte horizontale maximale et la contrainte horizontale minimale sont égales respectivement à 1,9 ± 0,12 et 1,1 ± 0,07 fois la contrainte verticale mesurée.

Les résultats des évaluations actuelles des contraintes dans les piliers ne sont pas concluants et d'autres mesures de surcarottage sont requises pour vérifier les données de contraintes obtenues.

Mots-clés : Contraintes d'exploration préliminaire; contraintes dans les piliers; mesures de surcarottage.

*Chercheur scientifique; **Spécialiste des sciences physiques, Laboratoire d'Elliot Lake, CANMET, Énergie, Mines et Ressources Canada, Elliot Lake (Ontario).

CONTENTS

	Page
ABSTRACT	i
RESUME	ii
INTRODUCTION	1
GEOLOGICAL SETTING AND MINING BACKGROUND	1
GROUND STRESS MEASUREMENTS	3
PRE-MINING STRESS DETERMINATION	6
PILLAR STRESS DETERMINATION	10
ACKNOWLEDGEMENT	13
REFERENCES	13

TABLES

No.		
1.	Strain recovery from overcoring measurements, pre-mining stress determinations	7
2.	Stress components, magnitude and orientation of the principal stresses; pre-mining stress determinations	8
3.	In situ stress measurements	10
4.	Strain recovery from overcoring measurements; pillar stress determinations	11
5.	Stress components, magnitudes, and orientations of the principal stresses; pillar stress determinations	12

FIGURES

1.	Location of H-W Mine, Westmin Resources Ltd.	2
2.	Longitudinal section of H-W Mine, Westmin Resources	4
3.	23 level plan and location of overcoring test sites; A) Pre-mining; and B) Pillar stress determination sites	5
4.	Orientations of the principal compressive stresses in an equal area net, lower hemisphere projection	9

INTRODUCTION

As part of a cooperative research project between CANMET and Westmin Resources Ltd. to evaluate the stability of barrier pillars at the H-W mine, B.C., ground stress determinations were conducted at the main mine workings. The following summarizes the results of pre-mining and pillar stress determinations carried out by the Mining Research Laboratory, Elliot Lake, Ontario.

GEOLOGICAL SETTING AND MINING BACKGROUND

Westmin Resources Ltd. operates a 4000 mtpd base metal mine/mill complex at the south end of Buttle Lake on Vancouver Island. The mine site, located in Strathcona Provincial Park, is accessed by a 90 km highway from Campbell River. Figure 1 shows the location of the H-W mine of Myra Falls Mining Operations.

The polymetallic massive sulphide orebody occurs at the base of the lowest of three mineralized rhyolite units in the Permian Myra formation. The main zone is a tabular deposit with dimensions of 850 x 220 m, and a maximum thickness of 60 m, of which about 35 m is economic. The orebody occurs at an average depth of 650 m below surface.

The main ore zone strikes NW/SE and is truncated on the northeast margin by a flat-lying fault. The North lens of the orebody lies to the northeast of the fault and has a maximum thickness of 25 m. The host rocks of the tabular orebody consist of volcanic and volcanoclastic andesite/rhyolite with stringer zones and interbeds of greywacke, argillite and chert. Andesite and rhyolite adjacent to the footwall and hanging wall have undergone intense sericite-chlorite alteration.

The dominant structural features include three steeply dipping joint sets, a series of flat-lying faults and two major cross-faults.

Access to the orebody is provided by a 700 m deep shaft with five

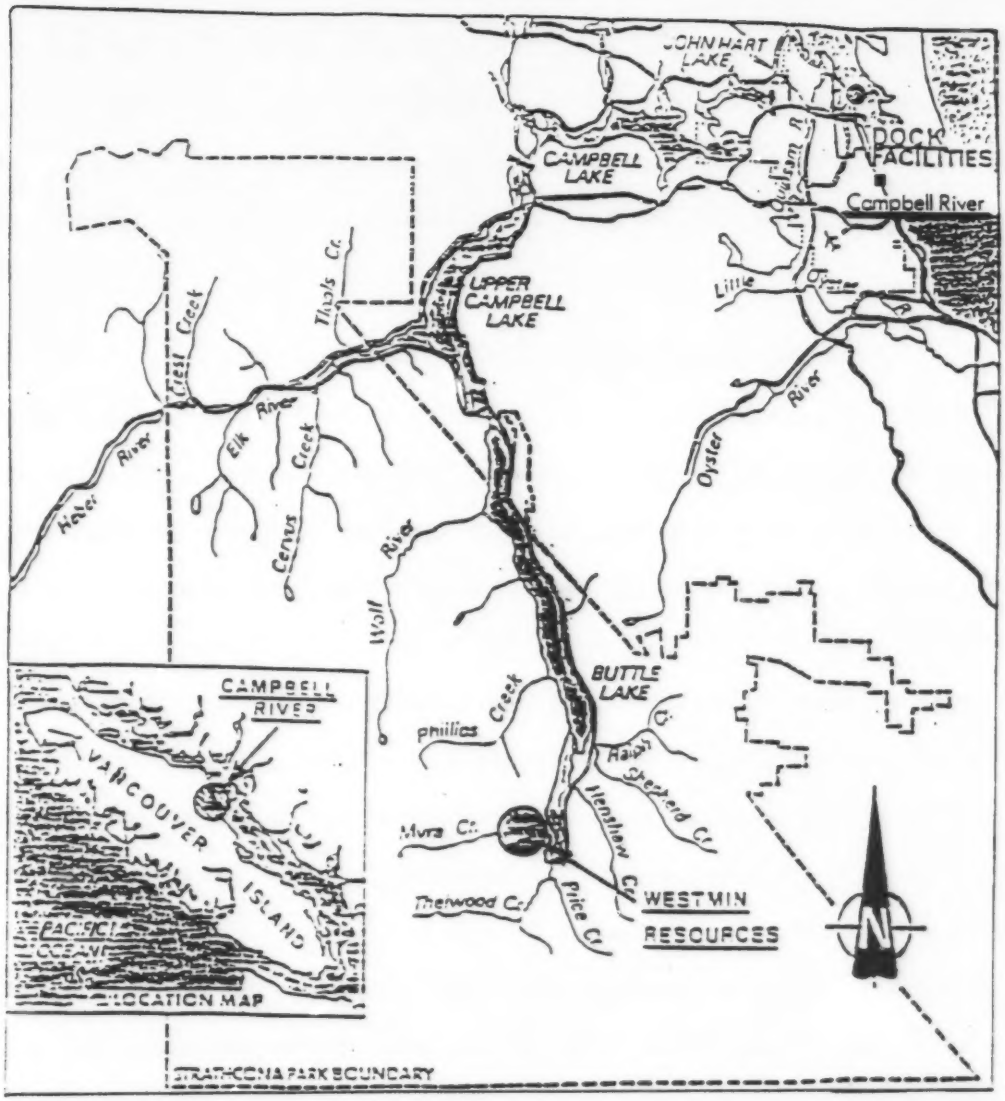

Fig. 1 - Location of H-W Mine, Westmin Resources Ltd.

levels developed for mining and exploration purposes. A cross-section of the mine is shown in Figure 2. Variations of several different mining methods are used for production which include: longitudinal cut-and-fill, cut-and-fill post-pillar, blast hole, and room and pillar. A cemented hydraulic backfill is primarily used for ground support. Details of geological and mining background are given in references 1-3.

GROUND STRESS MEASUREMENTS

To determine pre-mining stresses, the initial test site was selected on level 23 in a development drift in the North section of the mine. The test location, however, did not meet safety requirements and had to be abandoned, delaying the field work. A second site was selected on the same mine level in the West section close to the shaft. The stress measurement site was located in a drift with a cross-section of 20 square meters. The horizontal test hole ($+4^{o}$) was drilled in a fine-grained altered andesite/rhyolite at approximately 40^{o} to the main structural features.

The site for pillar stress measurements was located at approximately the centre of the mine workings on 23 level. The test hole ($+4^{o}$) in the pillar was drilled in a fine-medium grained massive sulphide ore. Figure 3 shows the general plan of 23 level, and the location of pre-mining and pillar stress measurement sites. Both test sites are located at an average depth of about 650 m below surface.

Stress determinations were carried out by overcoring measurements using CSIR triaxial strain cells. Successful bonding of strain cells in the EX-pilot hole was achieved using a two component gauge adhesive cement (Versilok HI-406). The cement mixture cured after 30 minutes at an ambient temperature of $+10^{o}C$, and overcoring commenced about one hour after the strain cells were installed. A total of eight overcoring tests were carried out.

An electrical Hydracore 25 HP drill machine was used to drill a 99 mm

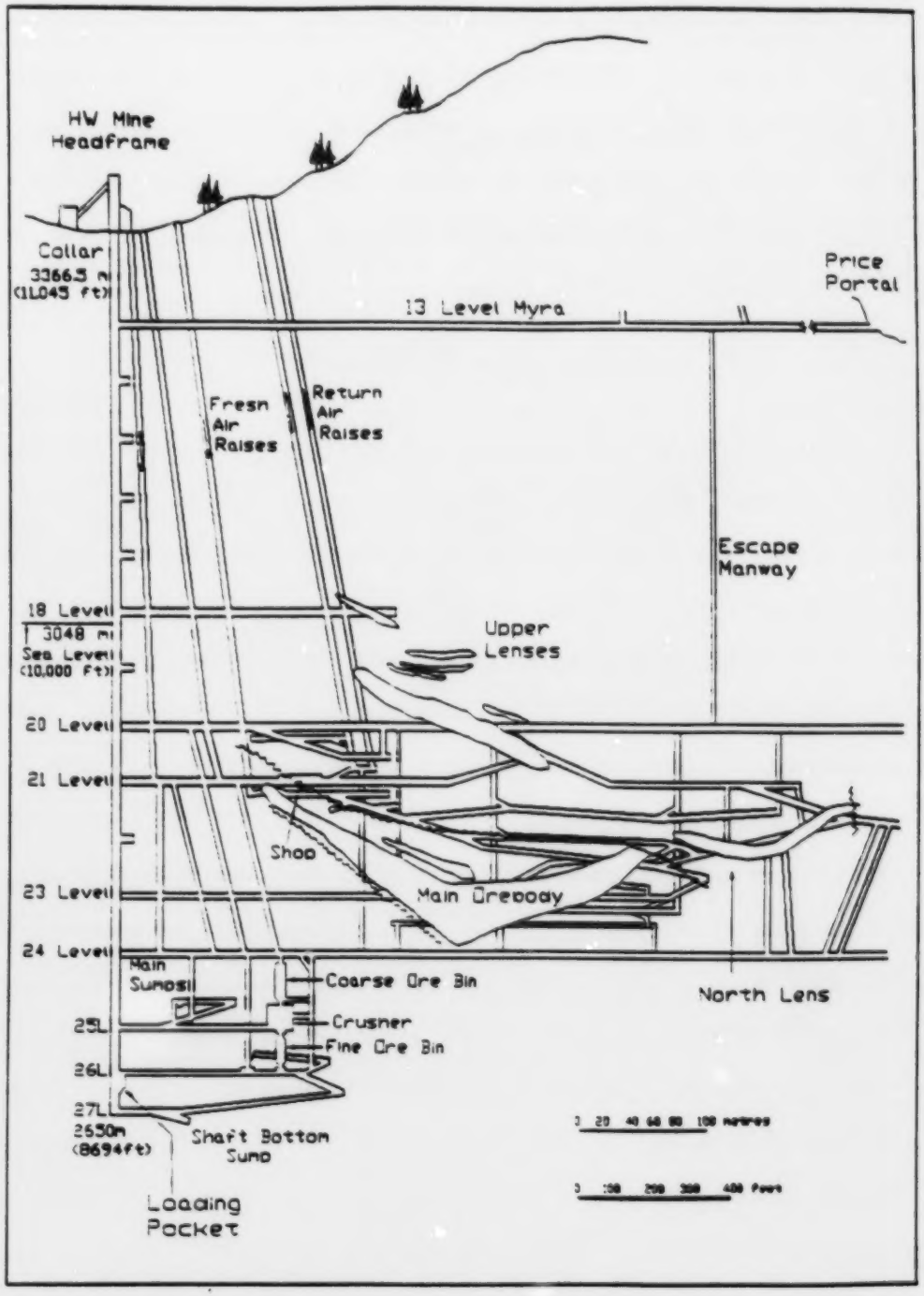

Fig. 2 - Longitudinal section of H-W Mine, Westmin Resources.

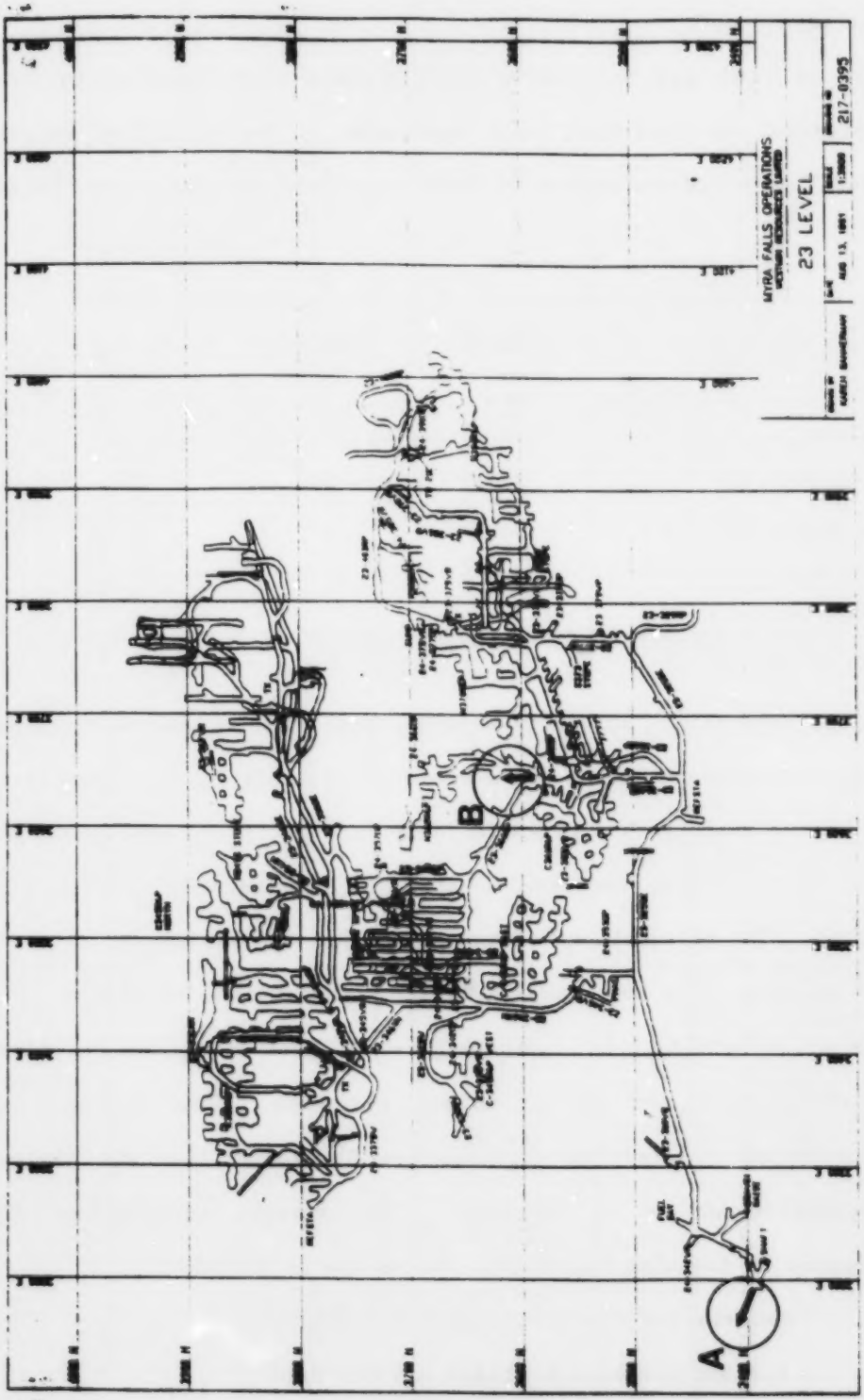

Fig. 3 - 23 level plan and location of overcoring test sites;
A) Pre-mining; and B) Pillar stress determination sites.

diameter hole which yielded an 83 mm diameter overcored test specimen containing the strain cell.

Elastic modulus and Poisson's ratio values were determined from uniaxial compression on overcored test specimens. The following average values obtained from a limited number of tests were used for the stress tensor calculations:

Rock Type	Elastic Modulus (GPa)	Poisson's Ratio	No. of Tests
Andesite/Rhyolite	57.2	0.23	2
Massive Sulphide, O/B	75.8	0.21	2

PRE-MINING STRESS DETERMINATION

The strain recoveries, strain invariances and depth of overcoring tests from pre-mining stress measurements are summarized in Table 1. The results of ground stress tensor analyses are given in Table 2. The stress components and the directions of principal compressive stresses are related to the mine coordinate system. The orientations of the principal compressive stresses are illustrated in an equal area net, lower hemisphere projection, in Figure 4.

The stress determinations indicate that a good correlation exists between the orientations of the principal stresses. The maximum and intermediate principal compressive stresses are horizontal and the minimum principal compressive stress is vertical. The overall orientations for horizontal stresses in the mine coordinate system are as follows:

Maximum horizontal stress = N 114°E/04°

Minimum horizontal stress = N 025°E/18°

From the evaluation of magnitudes of ground stresses the following average pre-mining stresses and stress ratios were determined:

Table 1 - Strain recovery from overcoring measurements, pre-mining stress determinations.

Test No.	Depth (m)	Gauge No: 1	2	3	Elastic Strain Recovery (με) 4	5	6	7	8	9	10	11	12	SI(*) Rosette: A	B	C
HW-01	8.5	480	475	470	465	502	467	410	450	500	475	445	440	10	5	30
HW-02	9.1	590	510	495	590	545	550	665	680	670	650	630	590	15	20	60
HW-03	9.7	425	335	360	420	545	435	425	555	510	430	340	445	30	20	25

- Overcoring test at 7.6 m depth not successful.

(*) Strain invariance: $\varepsilon_1 + \varepsilon_3 = \varepsilon_2 + \varepsilon_4$.

Borehole orientation: $292^{o}/+4^{o}$.

Table 2 - Stress components, magnitude and orientation of the principal stresses; pre-mining stress determinations

Test No.	Stress Components (MPa) (Standard Errors)						Standard Deviation	Principal Stresses (MPa) Mag./Dir.		
	σ_{EW}	σ_{NS}	σ_V	τ_{EN}	τ_{NV}	τ_{VE}		σ_1	σ_2	σ_3
HW-01	31.0 (0.4)	20.2 (0.6)	17.9 (0.4)	-5.4 (0.3)	0.4 (0.3)	-1.1 (0.2)	0.15 --	33.4 112/04	18.0 021/17	17.8 258/82
HW-02	40.3 (1.1)	26.7 (1.8)	21.8 (1.1)	-8.3 (0.8)	1.5 (0.8)	-1.4 (0.6)	0.45 --	44.4 115/05	23.1 208/27	21.3 015/62
HW-03	27.5 (0.8)	20.8 (1.4)	16.4 (0.8)	-4.2 (0.7)	-0.1 (0.7)	-1.2 (0.5)	0.34 --	29.6 116/04	18.9 025/12	16.2 226/77

Note: Stress components and principal stresses orientation (Bearing/Dip in degrees) related to mine coordinate system (mine grid north = N45°E geographic north).
Elastic modulus = 57.2 GPa, and Poisson's Ratio = 0.23 used for stress tensor calculations.

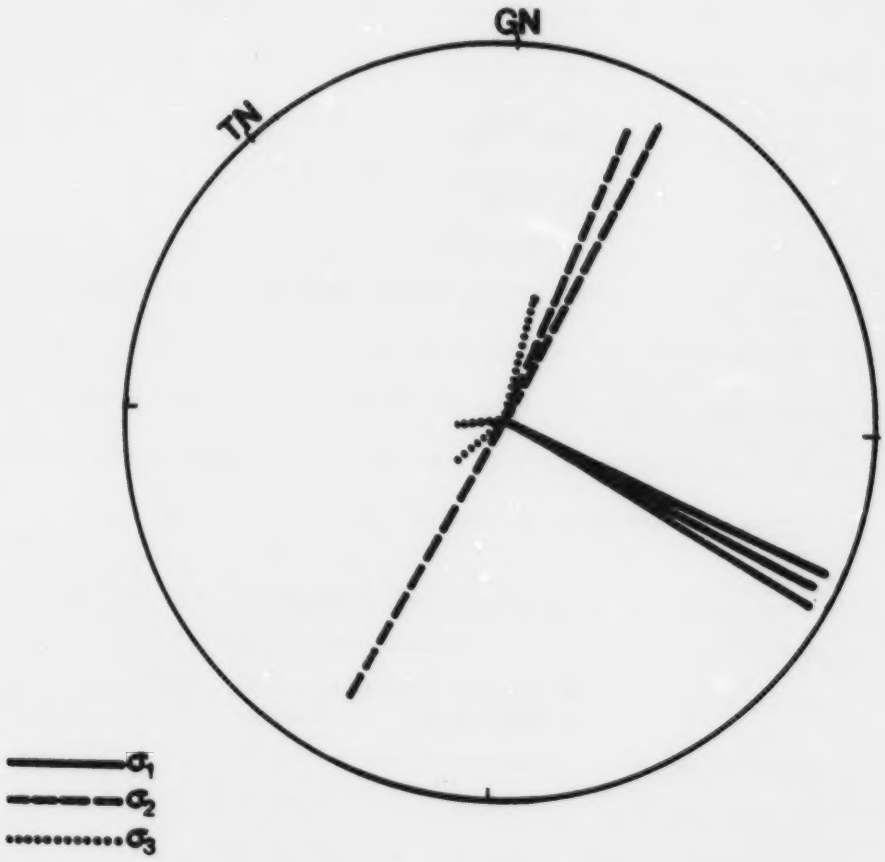

Fig. 4 - Orientations of the principal compressive stresses in an equal area net, lower hemisphere projection (Mine grid north = N45°E True north).

Maximum horizontal stress, σ_{Hmax} : 35.8 ± 7.7 MPa

Minimum horizontal stress, σ_{Hmin} : 20.0 ± 2.7 MPa

Vertical stress, σ_v : 18.7 ± 2.8 MPa

Sum of stresses, $\sigma_1 + \sigma_2 + \sigma_3$: 65.0 to 89.0 MPa

$\sigma_{Hmax}/\sigma_{Hmin}$: 1.8 ± 0.19

σ_{Hmax}/σ_v : 1.9 ± 0.12

σ_{Hmin}/σ_v : 1.1 ± 0.07

Previously, some limited overcoring stress measurements using biaxial CSIR strain cells (Doorstopper cells) were conducted on 23 level near the centre of the orebody (2). The principle of three test holes, drilled from the same set-up at different orientations, was used to determine the triaxial stress field. The stress determination results are given in Table 3.

Table 3 - In situ stress measurements

	Principal Stresses (MPa) Magnitude	Plunge
Maximum, σ_1	34.2	-27° to 021°
Intermediate, σ_2	27.5	-01° to 290°
Minimum, σ_3	15.2	-63° to 108°

The reported stress magnitudes and orientations are, generally, comparable to the data obtained from the present stress determinations. However, the strain recovery data and input parameters used for stress analyses were not available for a further comparison of results.

PILLAR STRESS DETERMINATION

The strain recoveries and depth of overcoring tests from pillar stress determinations are given in Table 4, and Table 5 provides the results of stress tensor analyses.

Table 4 - Strain recovery from overcoring measurements; pillar stress determinations

Test No.	Depth (m)	Gauge No: 1	2	3	Elastic Strain Recovery (με) 4	5	6	7	8	9	10	11	12	SI(*) Rosette: A	B	C
HW-P1	7.0	185	225	170	50	100	55	15^{+}	60	250	215^{+}	60	30	80	0	65
HW-P2	7.9	565	355	-80	80	710	650^{+}	300	270	295	270	260^{+}	225^{+}	50	90	60
HW-P3	8.4	185	240	90	80	310	190	180	330	170	300	250	160	44	30	40

($^{+}$) Adjusted strain readings.

(*) Strain Invariance: $\varepsilon_1 + \varepsilon_3 = \varepsilon_2 + \varepsilon_4$

Borehole orientation: $356^{o}/+4^{o}$

Table 5 - Stress components, magnitudes, and orientations of the principal stresses; pillar stress determinations.

Test No.	Stress Components (MPa) (Standard Errors) σEW	σNS	σV	τEN	τNV	τVE	Standard Deviation	Principal Stresses (MPa) Mag./Dir. σ1	σ2	σ3
HW-P1	6.5 (1.8)	8.6 (2.9)	7.6 (1.8)	1.5 (1.4)	-0.7 (1.4)	1.8 (1.0)	0.54 --	9.4 213/12	8.7 320/55	4.5 115/32
HW-P2	22.3 (4.2)	19.5 (6.8)	20.6 (4.2)	-2.5 (3.3)	-1.1 (3.3)	4.9 (2.4)	1.24 --	26.7 103/36	20.7 348/30	15.1 230/39
HW-P3	11.6 (1.4)	18.9 (2.3)	9.3 (1.4)	2.1 (1.1)	-1.1 (1.1)	-1.1 (0.8)	0.42 --	19.6 015/07	11.3 108/18	8.9 264/70

Note: Stress components and principal stresses orientation (Bearing/Dip in degrees) related to mine coordinate system (mine grid north = N45°E geographic north). Elastic Modulus = 75.8 GPa, and Poisson's Ratio = 0.21 used for stress tensor calculations.

As a result of instrument malfunction and difficulties in obtaining reliable and acceptable strain readings, the results from pillar stress measurements are questionable and not conclusive. Further overcoring measurements at this site and/or additional locations are required to verify the determined stress values.

ACKNOWLEDGEMENT

The cooperation of H-W mine, Westmin Resources Ltd., especially M. Cullen, Ground Control Engineer, for conducting part of the pillar stress measurements is greatly appreciated.

REFERENCES

1. Walker, R.R., "Westmin Resources' massive sulphide deposits, Vancouver Island"; Internal Report, Westmin Resources Ltd., P.O. Box 8000, Campbell River, B.C., 1985.

2. Chance, A. and Brodie, J., "Rock mechanics at Westmin Resources Ltd.'s H-W Mine"; Internal Report, Westmin Resources Ltd., Myra Falls Operations, P.O. Box 8000, Campbell River, B.C., 1987.

3. Petrina, M., "Underground mining methods at Westmin Resources Ltd.'s H-W Mine"; Internal Report, Westmin Resources Ltd., Myra Falls Operations, P.O. Box 8000, Campbell River, B.C., 1988.